Precipitation Estimate and Bias Adjustment

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Established in 1993 as a nonprofit research, technology transfer, and training organization. HRC’s objectives are to help bridge gaps between scientific research in hydrology and applications for the solution of important societal problems that involve water.

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Satellite Precipitation in FFG Systems

The CARFTG System is presently being prepared for on-site deployment. During this preparation, the interface and displayed data contents availability may be occasionally interrupted.

Current Date: 2017-10-29 09:41 UTC
Nav Date: 2017-10-29 03:00 UTC

Year: 2017 Month: 10 Day: 29 Hour: 03 REGION: REGIONAL

Prev 6-hr Interval (00 UTC) Recall to Current Next 6-hr Interval (06 UTC)

DT
01-hr
MWGHE Precipitation GHE Precipitation WRF D01 Forecast Gauge MAP Merged MAP ASM FFG IFFT PFFT
03-hr
06-hr
24-hr

Composite Product: text, CSV, CSV3
SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2017/09
Surfnet Gauge Observations at 2017-10-29 00:00 UTC
Hydro- Estimator National Environmental Satellite, Data, and Information Service (NESDIS) (NOAA)

- Real-time operational since August 2002
- Available globally (60N-60S)
- Hourly values for about 4 km.
- Geo-stationary GOES satellites IR 10.7 micron.
- Data are produced at the full instrument resolution and are updated whenever new imagery becomes available, with a latency of less than 15 minutes.
Geo Stationary Satellite that cover Central Asia

HIMAWARI

METEOSAT

EUMETSAT’s geostationary satellite coverage

IODC – Indian Ocean Data Coverage
GHE: Rainfall rate based on Cloud Top Brightness Temperature (*indirect measurement*)

- Produced by NOAA/NESDIS
- Research on satellite precipitation
  - since late 1970s;
  - Hydro-Estimator since 2002;
  - GHE Operational in 2012.
- Infrared (IR)-based, 10.7 mm
- **Short latency** (< ½ hour)
- ~4km resolution

Enhanced for:
1. Atmospheric moisture effects
2. Orography (upslope/downslope)
3. Convective Eqhb. Level (warm-top convection)
4. Local pixel temperature differences
5. Convective core / no-core region
Geostationary Operational Environmental Satellite - R Series (GOES-16 temporarily named GOES-R)
Launched in Nov 19, 2016
GHE (as of Nov 2017):
GOES-16 not incorporated
Meteosat-8 incorporated
Himawary-8 incorporated

QPE:
- 2km
- 4-time per hour
- Latency ~5min
- Using 5 IR bands
- Calibrated with MW

FFGS short term plan to incorporate all new satellites in 4km^2 GHE

In future FFGS the 2km^2 GHE will be used

http://www.goes-r.gov/products/ATBDs/baseline/Hydro_RRQPE_v2.0_no_color.pdf
Multi-Spectral Satellite Rainfall for FFG Systems

HRC effort to combine IR-based GHE rainfall with MW-based CMORPH rainfall

CMORPH is based on measurements of microwave scattering from raindrops.
- measure of the hydrometeors in clouds
- still not observation of rainfall at surface

High-Resolution Satellite Estimates

- CMORPH: CPC Morphing technique (Joyce et al. 2004)
  - Combined use of satellite PMW and IR data
  - 8km x 8km / 60°S-60°N;
  - 30-min interval / from September 2000 / Real-time
  - Project on the way to back-extend the CMORPH to 1998
  - Sample for August 18, 2003
Multi-Spectral Satellite Rainfall for FFG Systems

**GHE**
- Infrared – based
- Measurements of brightness temperature at the top of the cloud
- 30-min latency in operations
- ~4km resolution

**CMORPH**
- Microwave – based
- Measurements of microwave scattering from raindrops
- 18-26 hour latency in operations
- ~8km resolution
- No estimation over snow

FFGS Product combines IR-based GHE with MW-based CMORPH: MWGHE
Multi-Spectral Satellite Rainfall for FFG Systems

Window of 3 days

CMORPH Latency
Remotely-sensed precipitation estimates provide good spatial coverage and detail. In situ observations (gauges) provide “ground truth”.

- Satellite estimates do not measure precipitation!
- Bias may exist in remotely sensed precipitation.
- Bias should be removed for “best estimate” to provide input to hydrologic models.
Precipitation Adjustments Using Real-Time Rain Gauges

2 Steps:

• a climatological bias adjustment technique
  – quantile-quantile mapping between the log transformed areal-average gauge precipitation radar

• a dynamic bias adjustment technique.
  – adaptive Kalman filtering for the logarithmic ratio of the gauge to the radar precipitation averages over the same pre-specified area
Real-time Implementation of Bias Adjustment

Satellite Precipitation (MWGHE / GHE)

Evaluation of Regional Precipitation

Apply Regional Climatological Bias Adjustment

Climatologically-Adjusted Satellite Precipitation

Real-Time Dynamic Bias Adjustment

Mean Areal Precipitation (MAP) Computation and Merging

Other Models

This presentation discusses climatological bias calculations
Merged Mean Areal Precipitation (MAP) Product

CARFFG - Central Asia Regional Flash Flood Guidance

![Image of the CARFFG interface with data for different time intervals (01-hr, 03-hr, 06-hr, 24-hr) and various precipitation types (MVGHE Precipitation, GHE Precipitation, Gauge MAP, Merged MAP, ASM, FFG, IFFT, PFFT)].

Composite Product: test, GFV, DAYT
SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL 2015/05/13

Surface Gauge Observations at 2015-05-13 12:00 UTC

<table>
<thead>
<tr>
<th>Station Identifier</th>
<th>Station Name</th>
<th>Accumulated Precipitation (mm)</th>
<th>Event Temperature (°C)</th>
<th>Elevation</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Enable Precipitation Time</th>
<th>Enable Temperature Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>No reports for region</td>
<td>No reports for region</td>
<td>No reports for region</td>
<td>No reports for region</td>
<td>No reports for region</td>
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<td>No reports for region</td>
</tr>
</tbody>
</table>
Climatological Bias Regions

- STEP 1: Identify locations
- STEP 2: Define sub-regions
- STEP 3: Extract time series of satellite pixel (both GHE and MWGHE) gauge data pairs
Satellite Precipitation Bias Adjustment

Log Bias:

\[ \beta_t = \ln \left( \frac{\sum_{j=1}^{NG} R_G (j, t) / NG}{\sum_{j=1}^{NG} R_{SAT} (j, t) / NG} \right) \]

This is foundation of both the real-time and climatological bias adjustment.
Goal is to determine long-term bias in satellite precipitation within a given region using historical records

- Hydro-climatic sub-regions
- Monthly or Seasonal basis
- Approach can involve mean values or probability matching

**a. Mean Values**

**b. Probability Matching**
Dynamic Bias Adjustment

\[ \beta_t = \ln \left( \frac{\sum_{j=1}^{N_g} R_g(t, j)}{\sum_{j=1}^{N_g} R_s(t, j)} \right) \]

\[ \beta_{t+1} = \beta_t + w_{t+1} \]

\[ z_{t+1} = \beta_{t+1} + v_{t+1} \]

Kalman Filter
Stochastic Approximations

- N pairs of consecutive values > Nthr
- At least Xthr% raingauges with rain
- Conditional Mean > Threshold (mm/h) (satellite/radar and gauge)

Bias (B)

Georgakakos 1984
Available Stations for CARFFGS
Dynamic Bias Adjustment

Kalman Filter Prediction of the hourly bias adjustment

Modrick et al., 2016 & Georgakakos 1984
General Methodology for Climatological Bias Analysis

- Gather available historical gauge data *with* gauge coordinates (often use data records due to greater number of stations, number of historical gauges often > real time locations)

- Define sub-regions based on topography, climate, number of gauges, and spatial distribution of stations.

- Extract time series of precipitation for selected gauges and corresponding satellite pixel.

- Compute time series of log bias within each region subject to constraints:
  - Minimum # pairs with precipitation within region
  - Conditional average at given timestep > precipitation threshold

- Compute an average log bias on monthly or seasonal basis OR probability deciles for each region and determine climatological bias factor.
Final Comments on Bias Adjustment

- Climatological precipitation bias adjustment should be reviewed and updated on regular basis (every 2-3 years) with operational personnel. Updates could include additional stations (i.e., not in real-time archive) with consistent resolution using utilities that we will provide during training.

- Note: No precipitation bias adjustment is performed for FORECAST precipitation product.